Evaluation of the potential value of the F1H and F2H Diatomaceous earth formulations as grain protectants against Rhyzopertha dominica (Fabricius) (Coleoptera: Bostrichidae)

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Evaluation of the potential value of the F_1H and F_2H Diatomaceous earth formulations as grain protectants against *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae)

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Abstract

An insecticidal efficacy of two **newly developed** grain protectant formulations were assessed against lesser grain borer *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) on wheat and corn after 6 months period of. Tested formulations, marked as F_1H and F_2H, based on inert dust, laurel leaves, lavender essential oil, corn oil, silica gel (both F_1H and F_2H) and pyrethrin (only F_2H) were tested at six doses (from 100 ppm to 600 ppm) depending on formulation and type of grain. The appropriate weights of each formulation, were added seperately to plastic containers containing 10 kg of wheat or corn. An initial population of 200 adults of *R. dominica* were added into each container and left under natural environmental conditions for up to 6 months. A commercial diatomaceous earth (DE) insecticide, Celatom® Mn 51, was used for the comparison of the results, in addition to the untreated control. After six months, both formulations showed higher insecticidal effect than DE Mn 51 in corn and in wheat. Furthermore, the initial population of *R. dominica,* introduced in wheat was suppressed almost completely, with only 0.7%-5.3% live adults found, depending on formulations and dose. The order of efficacy was $F_1H>F_2H>$DE Mn 51. Similar suppression of the initial population was recorded in corn, where F_2H was slightly more effective than F_1H with 2.0%-10.6% and 4.1%-9.5% live adults found, respectively. At the same time, in the treatments with DE Mn 51 there were 4.7%-74.7% and 33.4%-56.1% live adults in wheat and corn, respectively.

Keywords: inert dust, botanicals, grain protectant, stored product insects, insecticidal effect

Introduction

Minimising food commodity losses, both qualitative and quantitative, during longer period of storing represents a main challenge for all economies. Stored-product insects play a significant role in postharvest losses, causing losses in grain weight, affects on baking quality and seed viability (Sánchez-Mariñez et al., 1997; Stejskal et al., 2015), which lower cereal market value. The use of synthetic insecticides is globally the most common way of controlling stored product insect pestsof the negative effects of pesticides on stored products includes: toxic residues (Fang et al., 2002), resistant strains within the insect populations (Chaudhry, 2000; Boyer et al., 2012), adverse effect on human health and environment (Fields and White, 2002). Thus there is an urgent need for alternative strategies which would be sufficiently effective against insects but less toxic for the environment.

The use of inert dusts, especially diatomaceous earth (DE), suits most of those requirements. Its main advantages are low mammalian toxicity and stability (Maceljski and Korunic, 1972; Subramanyam and Roesli, 2000) and an efficient insecticidal activity without leaving hazardous residues (Korunic, 1998; Shah and Khan, 2014; Liška et al., 2015; Korunić et al., 2017.). Despite this there are several limitations which hinder wider commercial use of DE for direct mixing with grains and are described by Korunić (2016). Diatomaceous earths, inert dusts in general, have physical mode of action and therefore act more slowly than conventional contact insecticides. Depending greatly on ambient conditions, it could take a several days to control most target insect species (Korunić et al, 2016), providing enough time for oviposition. Further, there are different sensativities of insect species to DEs, varying effects of DE on insects depending upon the commodity being treated and a negative effect on bulk density (Korunic, 2016; Korunić et al, 2017). Possible solutions for minimising or avoiding those implications include incorporating DE with other methods, such as extreme temperature (Dowdy, 1999), mixture with synthetic insecticides (Athanassiou, 2006; Korunic and Rozman, 2010), mixture with entomopathogenic fungi (Batta and Kavallieratos, 2018) or with botanicals (Korunic et al, 2014; Adarkwah et al, 2017).

Most experiments with inert dusts and their mixtures are carried out in controlled conditions, and less in the real conditions where various environmental and storage conditions could impact efficacy and subsequently, storage duration of the commodity.

The objective of this study was to test insect activity of two new developed formulations based on Croatian inert dust, bay leaves, lavandin essential oil, bait, corn oil, silica gel and pyrethrin against *R. dominica* in wheat and corn grain after six months period of storage.

Materials and Methods

Test insects

A local strain of *R. dominica*, was used in the experiments. Insects were reared on clean soft whole wheat kernels under controlled conditions (28±2°C, 65±5% RH, in dark). Two hundred, unsexed adults (7-21 days old) were used for each treatment.

Commodity

Locally available commercial corn and soft wheat were used in the treatments. Commodities were sifted prior to tests in order to segregate broken kernels and other impurities. Grain moisture content and grain temperature were measured by the GAC 2100-Agri Grain analysis computer (Dickey-john). The initial measurements were 11.1 % m. c. and 23.2°C for wheat, and 10.7 % m. c. and 23.3°C for corn. Ten kg of clean wheat and corn grain was used for each treatment.

Formulations

Two powder formulations labelled as F_1H and F_2H, were based on an inert dust of Croatian origin, dried and milled bay leaves, essential oil of lavandin (Lavender x Intermedia), bait, corn oil, silica gel and pyrethrin (only F_2H). A commercial DE insecticide, Celatom® Mn 51, was used for the comparison of the results. It belongs to a group of DE's with medium to high efficacy against stored-product insects. Formulations and DE were tested at different doses depending on the treatment. In wheat, F_1H and DE Celatom® Mn 51 were tested at 300, 400 and 500 ppm, and F_2H at 100, 150 and 200 ppm, while in corn F_1H and DE Celatom® Mn 51 were tested at 400, 500 and 600 ppm, and F_2H at 200, 250 and 300 ppm.

Bioassay

The dose rates of the tested formulations and DE were chosen based on results of preliminary laboratory test (unpublished data). Plastic containers of 15 L volume were filled with 10 kg of clean wheat or corn respectively. The appropriate weights of the formulations or Celetom DE were added into each container and mixed thoroughly with a power drill. Containers with untreated grain served as controls. After the dust had settled, 200 unsexed, 7-21 days old adults of *R. dominica* were added into each container which were then closed with perforated plastic lids. The bioassay was conducted for six months storing the containers in a wooden structure which simulated an average floor warehouse. The air temperature during the entire period of storing varied between 18.5°C and 23.0°C and relative humidity between 55.0% and 82.0%. After the end of the bioassay trial, the entire content of the plastic containers was sieved and all insects, dead and live, were counted.

Results

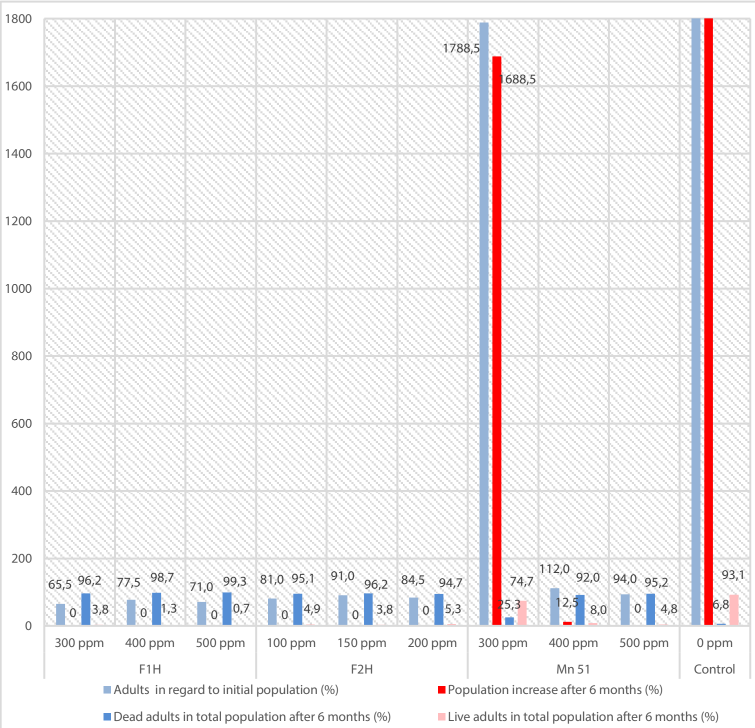
After six months of storing of treated corn and wheat, tested formulations F_1H and F_2H showed different efficacy against *R. dominica* depending on the cereal type and the applied dose.

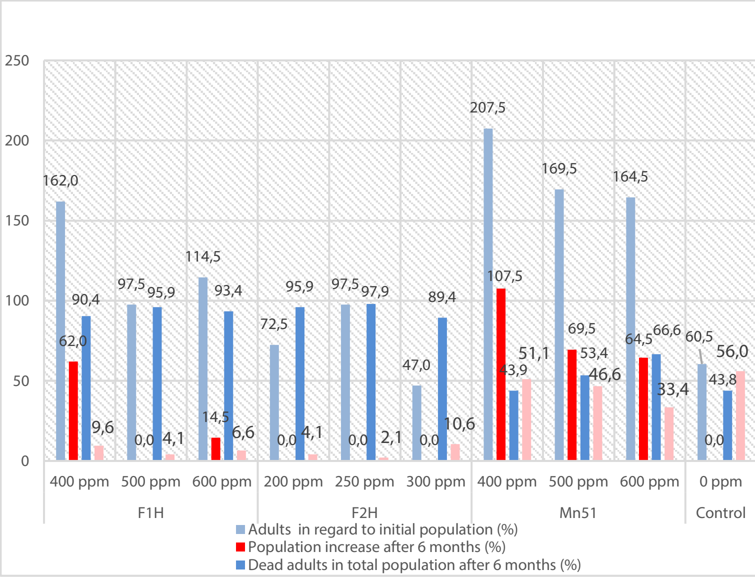
In wheat (Figure 1), both formulations successfully preserved grain quality against *R. dominica* during the period of six months. Even at the lowest dose, both formulations (300 ppm of F_1H and 100 ppm of F_2H) almost completely suppressed the initial population of *R. dominica,* therefore after six months, there was no population increase with only 0.7-3.8% (depending on dose of F_1H) and 3.8-5.3% (depending on dose of F_2H) of the original live adults found. For comparison, Celatom® Mn 51 at the lowest dose was not effective, resulting in a population increase (1688.5% higher than the initial population) within 74.7% live insects found. Population increases were also observed in the control treatment in wheat where number of insects from the initial 200 individuals increased up to 11817 within 93.13% live adults.

In corn (Figure 2), both formulations also showed better efficacy then Celatom® Mn 51. According to the number of adults found at the end of the testing period, formulation F_2H was more effective in regard to F_1H. Further, even at the lowest dose (200 ppm) no population increase was observed, while F_1H resulted with 62% and 14.5% of the population increase (at the dose of 400 ppm and 600 ppm, respectively). However, in the treatment with DE Mn 51, the highest dose (600 ppm) was not efficient enough to control *R. dominica,* and the population increase was in the range from 64.5 to 107.5% (higher than initial population) (depending on dose) within average of 45.4% live adults found. Concerning control treatments, unlike in wheat no population increase was observed in corn. Due to high temperature and high moisture content of the grain during six months fungi developed intensively and the whole stock become glued mass, so insects could not survived in those conditions.

Fig. 1 Efficacy of the formulations F_1H and F_2H against *R. dominica* after six months of wheat storing

Fig. 2 Efficacy of the formulations F_1H and F_2H against *R. dominica* after six months of corn storing





Discussion

Increased efficacy of the tested formulations against *R. dominica,* compared to DE alone was expressed because of the mixture of different active ingredients within their composition and due to their different modes of action. Besides inert dusts, the main composition of the formulations are the botanicals powdered bay leaves and lavandin essential oil. These compounds possess fast toxic activity against many coleopteran pests of stored products (Kostyukovsky et al 2002; Rajendran and Sriranjini, 2008; Nerio et al 2010; Koutsaviti et al, 2018). Comprised of volatile monoterpenoids and sesquiterpenenoids, the essential oils interfere with basic metabolic, biochemical, physiological and behavioural functions in insects possessing contact, inhalation and ingestion toxicity, antifeedant activity, developmental delay of adult emergence and fertility, different effects on oviposition and repellent activity (Obeng-Ofori 2007; Caballero-Gallardo et al, 2012; Nenaah 2014; Germinara et al, 2017). DEs and general inert dusts, with physical mode of action, are slow acting protectants (Korunic, 1998). Apparently, as a mixture of plant powders, essential oils and inert dusts, our formulations accelerate the knock down effect of the adults within the initial population of *R. dominica* which resulted in prevention of mating and reduced oviposition. Food grade bait composed within our formulation probably also accelerated insect mortality. Presumably, it attracted insects which kept them in the contact with inert dust for longer period. Consequently, insects picked up more inert dust particles on their body which led to faster desiccation (Korunić et al, 2016).

Adarkwah (2017, 2017a) reported faster activity of the mixture of DE and plant powders against three different stored product insects.While, mentioned authors conducted their trials in laboratory conditions and only during 7 days of exposure, our tested formulations secured effective control of the tested pest during the whole testing period of six months in conditions that might more realistically represent true storage conditions.

Overall two developed formulations, as a combination of inert dusts and botanicals could be promising insecticides with residual effect for protecting stored wheat and corn against insect infestation.

Acknowledgement

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based on inert dusts and botanicals to replace synthetic, conventional insecticides“, www.diacromixpest.eu.

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Olfactory host location and host preference of *Holepyris sylvanidis* (Hymenoptera: Bethylidae) and *Cephalonomia waterstoni* (Bethylidae), two natural enemies of *Tribolium* and *Cryptolestes* species

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Abstract

Parasitoids can suppress populations of their host and thus play a primary role in Integrated Pest Management. In the stored product environment, stimuli deriving from plant products, damaged plant products and hosts might be important for host location by the parasitoids. We studied foraging cues in *Holepyris sylvanidis* (Hymenoptera: Bethylidae), a larval parasitoid of *Tribolium* species and *Cephalonomia waterstoni* (Bethylidae), a natural enemy of the rusty grain beetle *Cryptolestes ferrugineus* (Coleoptera: Cucujidae). Our studies in a four-chamber olfactometer revealed that the host complexes of both *Tribolium* species and different living host stages attract naive *H. sylvanidis* females, whereas no reaction was observed to uninfested substrates. The olfactory response of *C. waterstoni* was found to be strongly elicited both by chemicals emitted by the dust, adult *C. ferrugineus* and *C. ferrugineus* third and fourth instar larvae. Our findings may contribute to the development of biological control strategies of *T. castaneum*, *T. confusum* and *C. ferrugineus* with parasitoids.

Keywords: natural enemies, Bethylidae, stored product pests, biological control

Introduction

The bethylid wasp *Cephalonomia waterstoni* Gahan is an external, arrhenotokous idiobiont larval ectoparasitoid. Hosts are *Cryptolestes ferrugineus* (Stephens), *C. pusillus* (Schönherr) and *C. turcicus* (Grouvelle) (Coleoptera: Cucujidae) (Finlayson, 1950a; 1950b). *C. waterstoni* is able to find hosts by recognizing residual kairomonal cues on infested substrates, similar to other parasitoids (Howard & Flinn, 1990). Hagstrum (1987) and Reichmuth et al. (2007) reported the ability of *C. waterstoni* to maintain the population of rusty grain beetles below the economic threshold.

The parasitic wasp *Holepyris sylvanidis* (Brèthes) (Hymenoptera: Bethylidae) is a larval parasitoid of *Tribolium confusum* Jacqueline du Val and *T. castaneum* (Herbst) (Coleoptera: Tenebrionidae), the economically most important stored product pests worldwide (Athanassiou et al., 2005; García et al., 2005). The host-searching behaviour of *H. sylvanidis* is influenced by the presence of host faeces, in which two compounds are thought to be responsible for the attraction: (*E*)-2-nonenal and 1-pentadecene (Fürstenau et al., 2016). The ability of *H. sylvanidis* to penetrate cracks and crevices makes it a promising natural enemy against stored-product pests. Pest larvae are often hidden under thin layers of substrate, in aeration ducts, in machines and in areas that are difficult to clean, but this wasp is able to access these critical environments.